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EROSION IN 7.62MM MACHINE GUN BARRELS

TECHNICAL REPORT

William T. Ebihara

December 1970

SCIENCE & TECHNOLOGY LABORATORY

RESEARCH & ENGINEERING DIRECTORATE

U. S. ARMY WEAPONS COMMAND

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ABSTRACT

Metallurgical analysis was conducted on 7.62mm machine gun barrels, in the chromium-plated and unplated conditions, to describe the erosion process. The chronological analysis involved the examination of severely eroded gun barrels as well as those subjected to test firings of 1 to 3000 rounds. Inherent defects in the form of cracks were noted in the chromium plate prior to firing. These cracks were extended to the chromium-steel interface as early as the first round; thus the underlying steel was exposed to the reactive environment. Continued firing resulted in the propagation of these cracks into the steel substrate followed by crack-branching. Branching proceeded until linkup was achieved, which resulted in the removal of chromium plate steel fragments. The factors considered to be responsible for crack extension include gaseous and liquid metal reactions. The type of erosion found in unplated steel gun barrels was in contrast with that of the plated barrels in that substrate-cracking was delayed and land wear occurred much earlier in the firing sequence.

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INTRODUCTION

Deterioration of the bore surface resulting from erosion remains a major problem in the performance of rapid-fire, high-velocity weapons. Generally, gun erosion is defined as the result of processes that lead to a change in bore dimensions. In this report, erosion is described as a change in the bore cross section resulting from material removal or structural alteration. In the initial stages, erosion may manifest itself in the decrease of projectile velocity or accuracy, thereby reducing the effectiveness of the weapon. Loss of velocity or accuracy becomes increasingly apparent as erosion progresses until the gun is withdrawn from the test.

The advanced stages of erosion introduce areas near the breech that are particularly susceptible to catastrophic failure. A cross section of such an area is shown in Figure 1. This segment was taken from a barrel that had actually failed at the breech end, causing the damage shown in Figure 2. Failures of this type not only completely render the weapon useless but also may be fatal to personnel in the vicinity of the weapon.

Only moderate success has been achieved in attempts to combat erosion in weapons. Approaches for solving the erosion problem have been mainly those involving techniques to reduce erosion by

1. utilization of erosion-resistant materials,
2. reduction of the bore surface temperatures, and
3. reduction of chemical and mechanical effects.

The first of the foregoing items was accomplished with some form of plating or lining on gun barrel steel. The latter two items have, in general, resulted from the utilization of lower combustion-temperature propellants, wear reducing propellant additives, and design changes of internal rifling-configuration. However, large gains in erosion reduction are still limited by the lack of fundamental knowledge concerning the mechanisms of erosion and the erosion rate-controlling parameters for any given weapons system. Once these conditions are established, a combined approach with materials, propellants, and design considerations can be effectively applied for optimization of weapons performance as well as for selection of a testing criterion to evaluate candidate materials for use in gun barrels.

Erosion studies in the past, on small caliber weapons, were generally conducted with emphasis on weapons of caliber .50 or larger.* The studies concerned the inspection of severely eroded structures on barrels of a homogeneous structure. Little basis for comparative analysis could be established since nonuniform firing schedules, propellants of varying composition, and different weapons systems were often used. Tests conducted to isolate various parameters were limited and, generally, terminated soon after 1946. Although the results of these studies are extremely helpful in the present investigation, many of the conclusions were too general in content to solve erosion problems of contemporary weapons systems.

The intent of the present effort is to determine the rate-controlling processes involved in the erosion of small caliber weapons systems so that satisfactory methods can be adapted to prevent or control this deterioration process. The first phase of the study involved an intensive analysis of the eroded structures to describe the character of the erosion phenomenon. Description of the chronological development of erosion and of the eroded structure was the objective of this phase. The object of the second phase will be an investigation of the effects of the various erosion parameters, both individually and in combination, through selective laboratory tests. Then, with the correlative findings of Phase I, the object will be the achievement of establishing the predominant erosion mechanism for the particular weapons system and propellant.

In this report, the progress of the study is recorded to describe the erosion in the 7.62mm machine gun barrel. Previously, endurance-fired gun barrels, with documented firing schedules, were analyzed. These data, describing the advanced stages of erosion, were then compared with results of selectively chosen test barrels, fired from 1 to 3000 rounds, to show the chronological development of erosion. Emphasis was placed on the type of erosion found in chromium-plated 7.62mm barrels, although comparisons were made with erosion of the same barrels in the unplated condition. Since this investigation is continuing, these results are considered preliminary.

*"Hypervelocity Guns and the Control of Gun Erosion," Summary Technical Report of Division 1, NDRC, Volume 1, Washington, D. C., 1946.

EXPERIMENTAL PROCEDURE

The 7.62mm gun barrels, in the chromium-plated and unplated conditions, were obtained for test-firing purposes. This weapon has six barrels and was fired at a rate of 4000 rounds per minute or approximately 667 rounds per minute for each of the six barrels. In most instances, duplicate tests were conducted for both the unplated and the chromium-plated barrels. Continuous individual bursts of 1, 10, 50, 100, and 200 rounds were applied to each type of barrel. To provide barrels that would be subjected to 300 rounds or more, the firing schedule for each barrel consisted of a 100-round burst, 15-second cool, 100-round burst, 15-second cool, and a final 100 round burst followed by a 30-minute cooling period. Multiples of this 300-round firing sequence were then used to provide gun barrels being subjected to a total of 900, 1500, 2100, and 3000 rounds. The ammunition used in these tests was the standard NATO M80, Lot TWL 13068 67, with WC 846 propellant.

The test-fired gun barrels were cleaned by an ethyl alcohol rinse and then dried. Silicone replicas were made to nondestructively examine the condition of the interior bore surface.

The gun barrels were sectioned longitudinally and the interior bore surface was again inspected. The majority of the samples for study were obtained from the first four inches from the origin of rifling since this area usually exhibits the maximum damage. Unless otherwise stated, the transverse cross-section represents a zone approximately one inch from the origin of rifling. Two types of specimens (a transverse section and a section polished at a low angle to the bore surface, which is referred to as a bore surface specimen) were prepared for examination purposes. The bore surface specimens were necessary to provide an enlarged viewing area of damage (for examination purposes) because the depth of erosion was not always appreciable and, consequently, could not be observed satisfactorily on a transverse section. These specimens were subjected to metallurgical analyses involving the utilization of the optical microscope, scanning electron microscope, electron microprobe, and X-ray diffraction techniques.

RESULTS

Initially several barrels that had been fired under severe schedules, and thus exhibited the advanced stages of erosion, were studied. The bore surface of these barrels had an appearance as shown in Figure 3. Much of the chromium plating had been removed, and copper had filled cracks in the barrel. The extent of copper extrusion into the cracks is better observed in the polished section of Figure 4. The cracks observed on the bore surface extended through the chromium and well into the underlying steel, as shown in Figure 5. Not all of the cracks in the steel exhibited copper, but the microprobe analysis revealed copper in some of the most minute cracks (Figure 6). The cracks became larger primarily in the radial direction, with some bifurcation noted. An altered zone was observed to be associated with the cracks in the steel. Examples representative of the appearance of the altered zone are shown in Figures 7 and 8. The zone appears to consist of more than one phase and to have resisted chemical attack by common etchants (nital and picral) as depicted in Figure 9. Identification of this zone or of the phases present is not yet complete. However, it is generally described as being considerably harder than the unaffected steel. Microprobe analysis revealed that this zone is of a different chemical composition than that of the unaltered steel as evidenced by the scan shown in Figure 10.

Inspection of the bore surfaces at 40X revealed a gradual accumulation of residue up to 300 rounds. However, no significant difference could be observed in the quantity of residue found in barrels fired 900 rounds and those barrels fired 3000 rounds. The residue appeared to be a mixture of copper, heaviest in the corners between land and groove (Figure 11) and a fused crust (Figure 12). X-ray diffraction analysis showed that the major phase of the crust was calcium carbonate, $CaCO_3$. The bore residue had accumulated more in the barrel area toward the muzzle end and was more prevalent in the chromium plated barrels.

Cracks appeared to inhere in the hard chromium plating as shown in Figure 13. These cracks became larger during repeated firing so that a crack network was obvious at a magnification of 40X even after only 50 rounds of fire. The exposure of the underlying steel to attack after only 10 rounds is illustrated in Figure 14. The reaction pits in the steel were always traceable to cracks in the chromium plate. After 100 rounds had been fired, the cracks were filled with copper and the network decorated with it (Figure 11). The copper in the cracks on the bore surface appeared as if it were extruded as the barrel material contracts following a pressure pulse. After 200 rounds, definite cracks were observed in the steel (Figure 15). Not all cracks in the steel originate at a pit underlying the chromium plate. However, both the pit and the crack in the steel were always observed to be associated with cracks in the chromium.

plated structure until after 900 rounds of firing. Therefore, the modes of the initial stages of erosion were sufficiently different for the two types of gun barrels. Overall wear or erosion was observed for the unplated steel as contrasted from the localized attack of steel substrate through cracks in the chromium plate. Further firing resulted in increased wear and noticeably altered surface layers, but relatively few cracks that penetrated to any excessive depth.

SUMMARY

Analyses involving light and scanning electron microscopy, electron microprobe and X-ray diffraction studies were performed on test-fired 7.62mm machine gun barrels in the chromium plated and unplated conditions to describe the erosion process. The following observations were made:

1. Inherent cracks in the chromium plate extended to the chromium-steel interface as early as the first round of fire.

2. Continued firing after the tenth round resulted in the propagation of radial cracks into the underlying steel and was followed by crack-branching at or below the chromium-steel interface.

3. A brittle, structurally altered zone, observed after 300 rounds of fire, was found to surround the erosion cracks.

4. Crack-branching proceeded until linkup was achieved, resulting in the removal of chromium-steel fragments at areas near the origin of rifling after 1500 rounds of fire.

5. Continued firing resulted in further radial propagation of the primary cracks.

6. The unplated steel gun barrels were differentiated by rapid land wear near the rifling origin early in the firing sequence.

7. Overall wear with few cracks of notable depth were typical of the test-fired, unplated barrels when compared with the localized deeper cracks observed in the plated gun barrels.

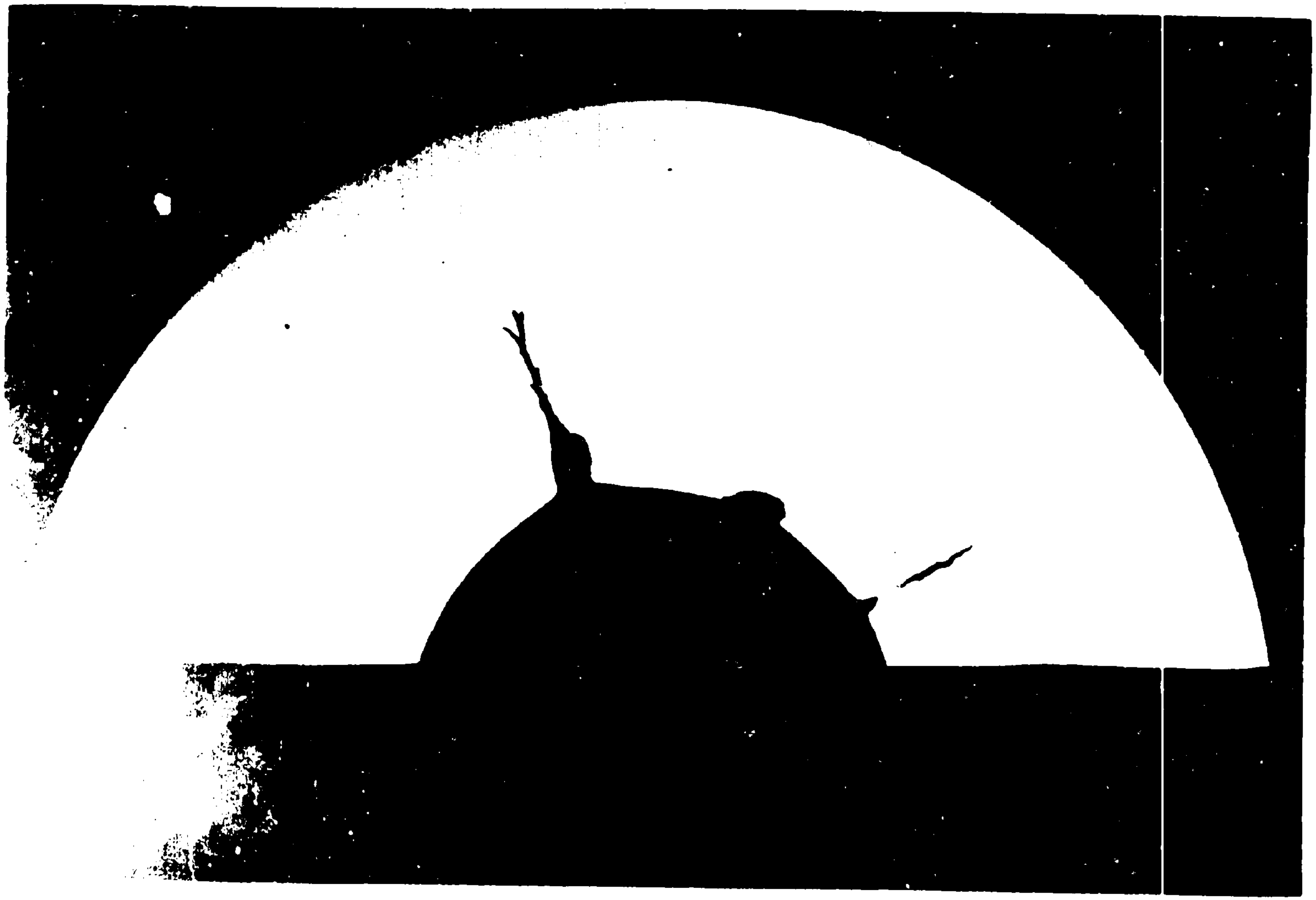

FIGURE 1 TRANSVERSE SECTION OF FAILED BARREL NEAR THE BREECH END

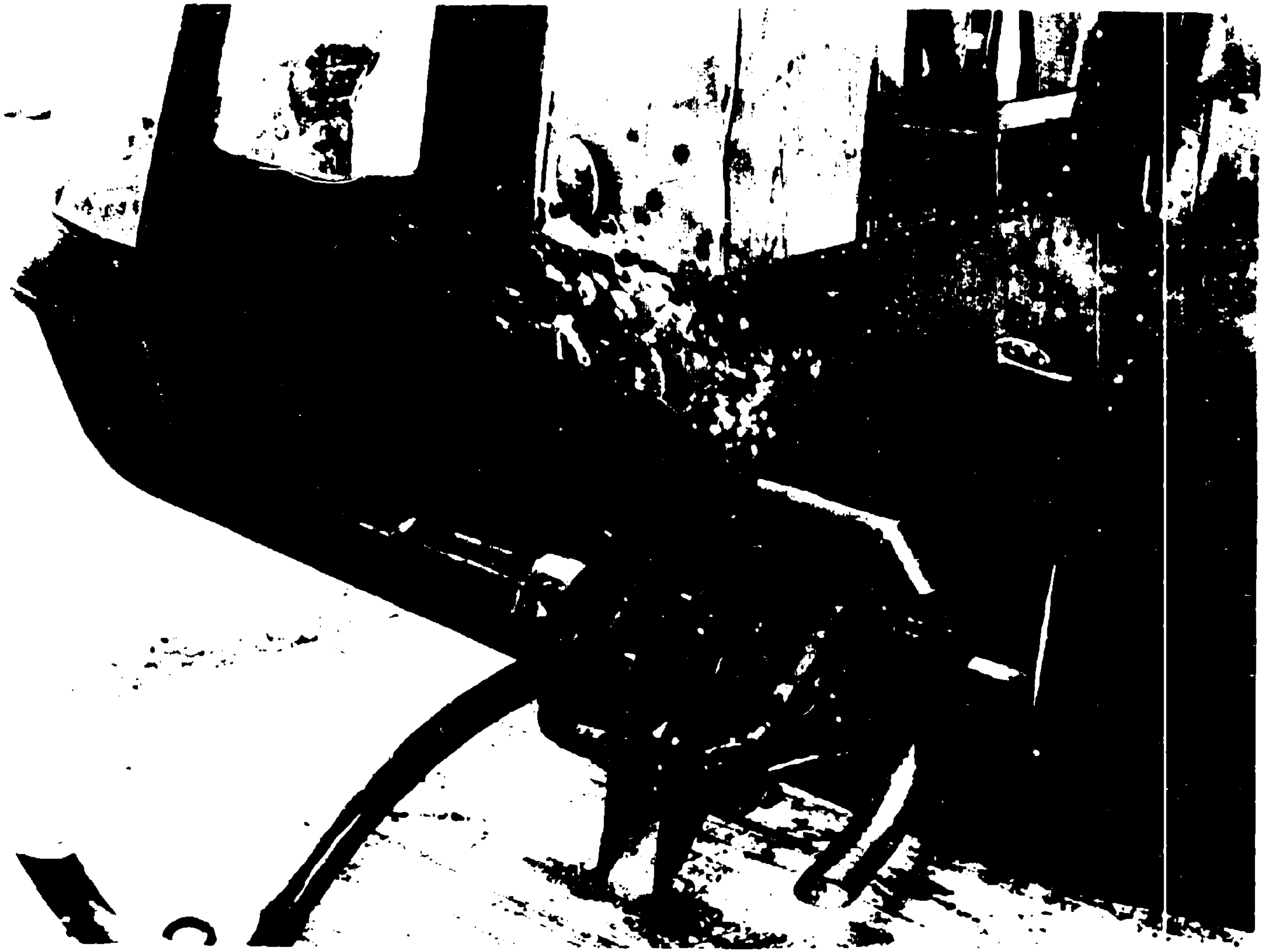

FIGURE 2 WEAPONS CARRIER AFTER BREECH END FAILURE OF MINIGUN BARREL

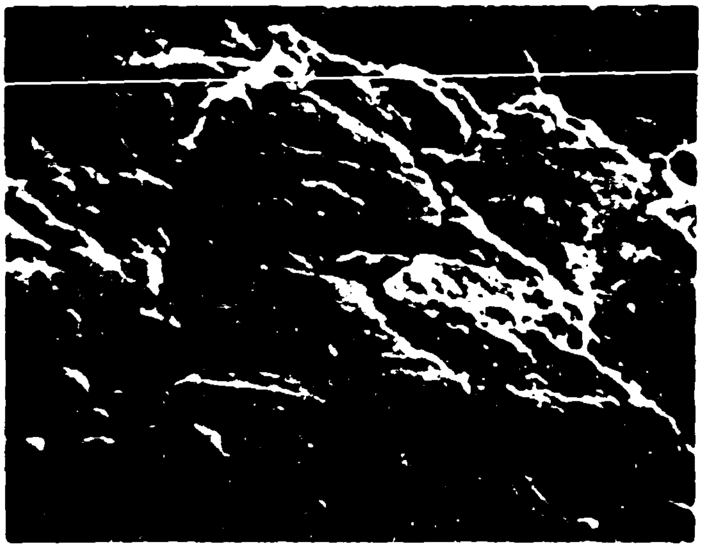

FIGURE 3 SCANNING ELECTRON MICROGRAPH OF ERODED BORE SURFACE

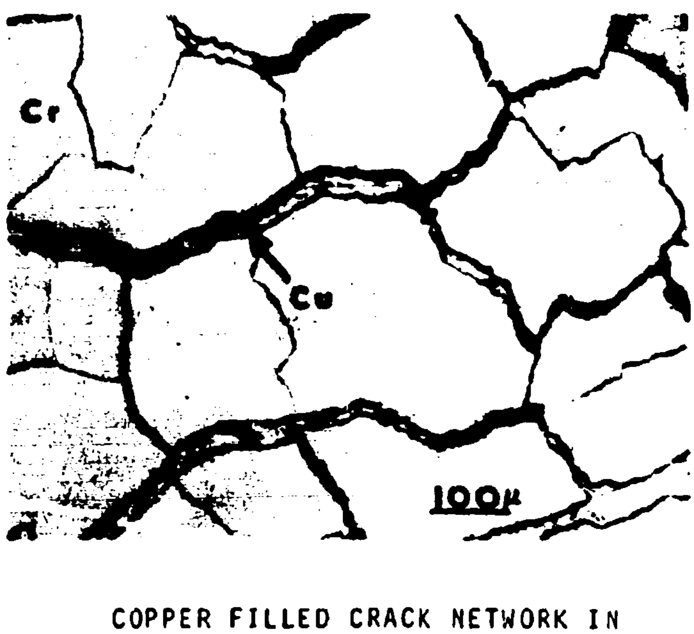

FIGURE 4 COPPER FILLED CRACK NETWORK IN CHROMIUM PLATING (unetched)

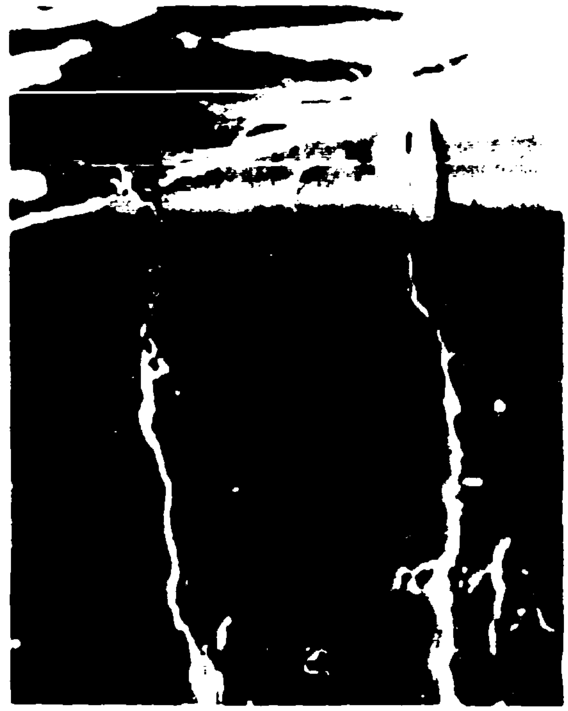

FIGURE 5 SCANNING ELECTRON MICROGRAPH SHOWING EXTENSION OF CRACKS INTO THE UNDERLYING STEEL

FIGURE 6 ELECTRON MICROPROBE X-RAY DISPLAY SHOWING COPPER IN MINUTE CRACKS IN STEEL

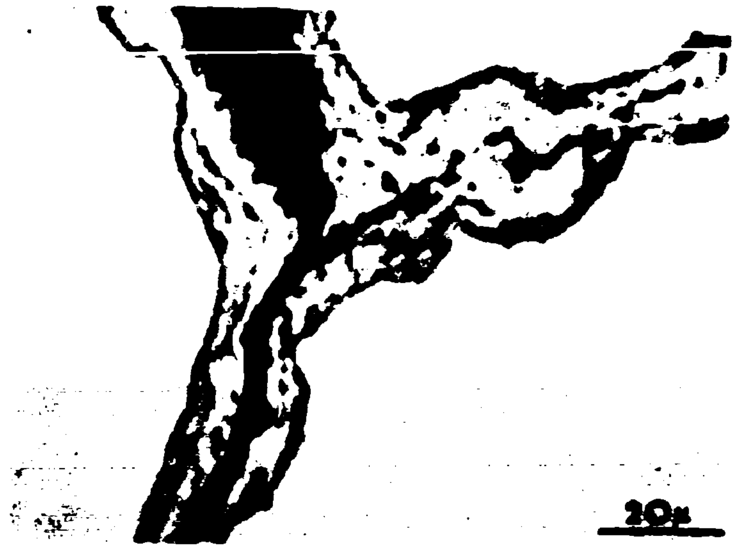

FIGURE 7 OPTICAL PHOTOMICROGRAPH OF ALTERED ZONE SURROUNDING A CRACK

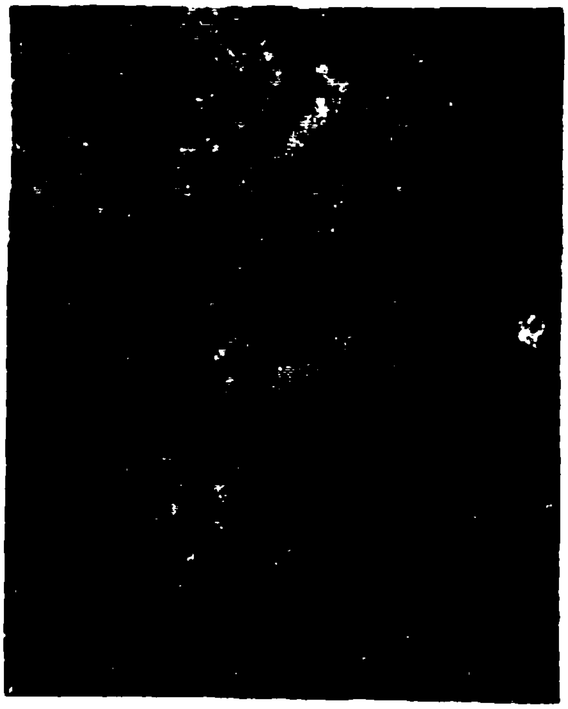

FIGURE 8 SCANNING ELECTRON MICROGRAPH OF ALTERED ZONE SURROUNDING A CRACK

FIGURE 9 STRUCTURE OVERETCHED TO REVEAL ALTERED ZONE (etched in nital)

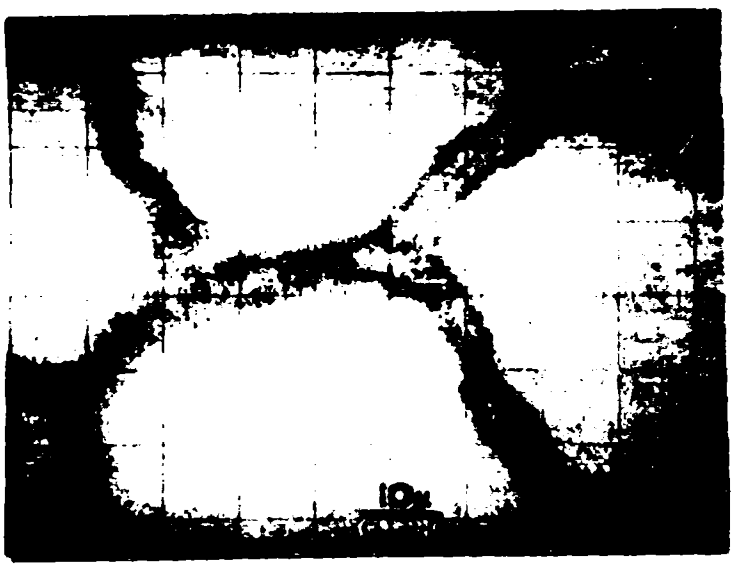

FIGURE 10 MICROPROBE ANALYSIS BY BACK-SCATTERED ELECTRONS TO DEFINE ALTERED ZONE

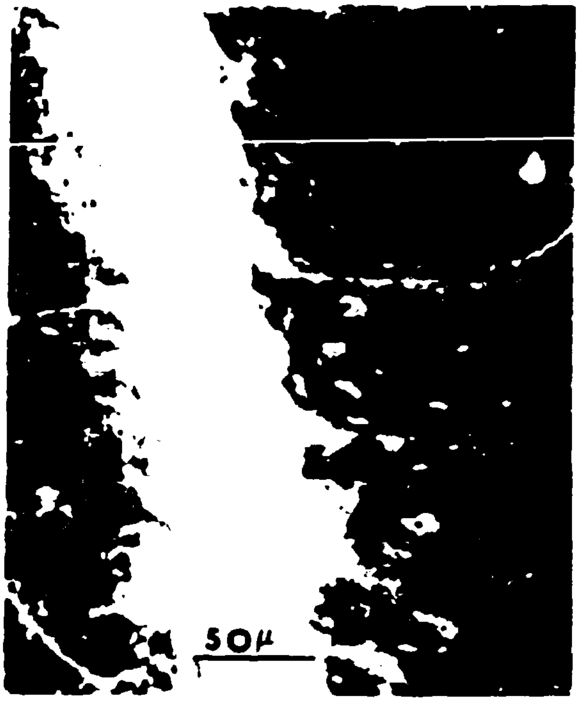

FIGURE 11 SCANNING ELECTRON MICROGRAPH SHOWING COPPER COLLECTED INTO CRACKS AND CORNERS OF BORE SURFACE

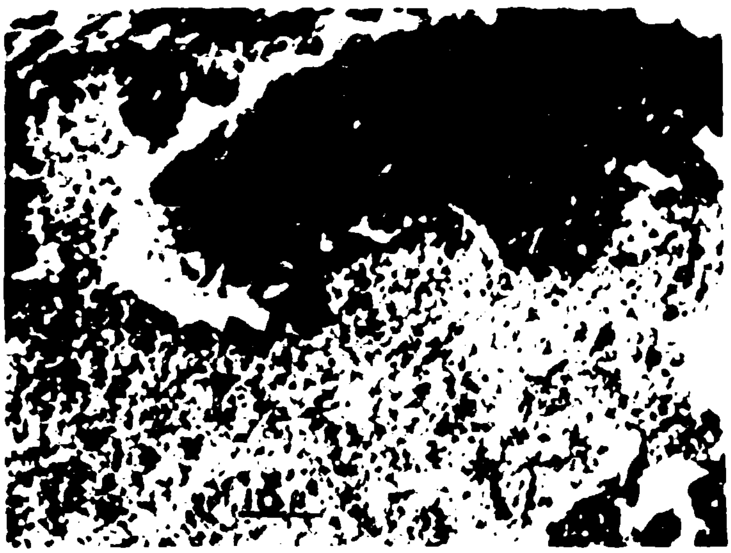

FIGURE 12 SCANNING ELECTRON MICROGRAPH SHOWING NONCOHERENT FUSED CRUST ON THE BORE SURFACE OF UNPLATED BARRELS

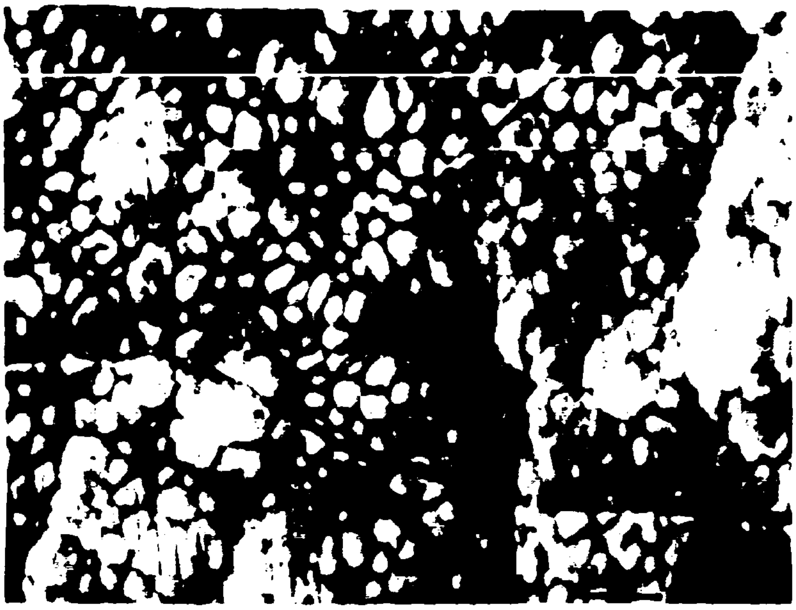

FIGURE 13 SCANNING ELECTRON MICROGRAPH REVEALING CRACK NETWORK INHERENT IN THE CHROMIUM PLATE

FIGURE 14 SCANNING MICROGRAPH SHOWING PITTING IN STEEL BENEATH CRACKS IN THE CHROME PLATE AFTER 10 ROUNDS

FIGURE 15 SCANNING MICROGRAPH OF CRACK PROPAGATING INTERGRANULARLY INTO STEEL AFTER 200 ROUNDS

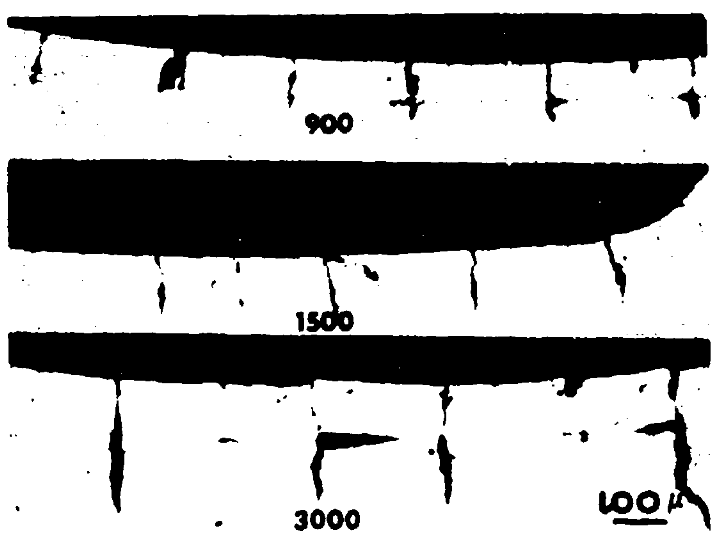

FIGURE 16 OPTICAL PHOTOMICROGRAPHS OF TRANSVERSE BARREL SECTIONS AFTER 900, 1500, AND 3000 ROUNDS (unetched)

FIGURE 17 SCANNING ELECTRON MICROGRAPH SHOWING FRAGMENTATION AND REMOVAL OF CHROME PLATE AFTER 3000 ROUNDS

FIGURE 18 OPTICAL PHOTOMICROGRAPH OF ALTERED ZONE SURROUNDING CRACKS AFTER 3000 ROUNDS (etched in nital)

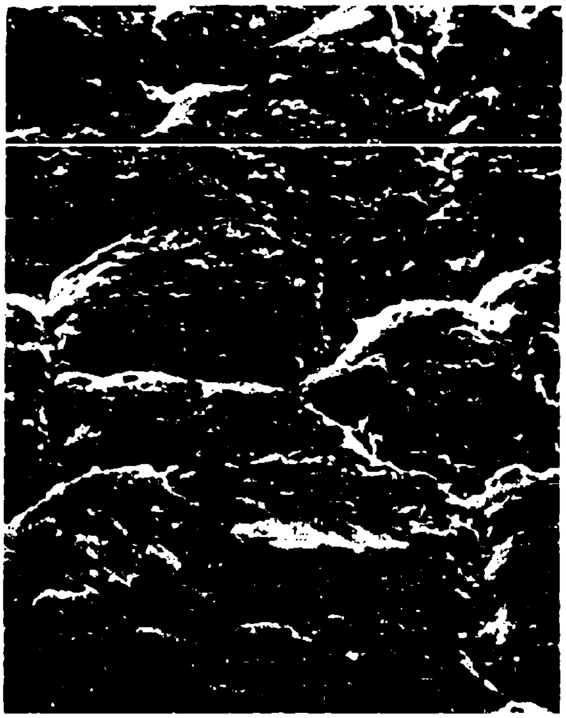

FIGURE 19 APPEARANCE OF BORE SURFACE OF UNPLATED BARREL AFTER 3000 ROUNDS (scanning electron micrograph)

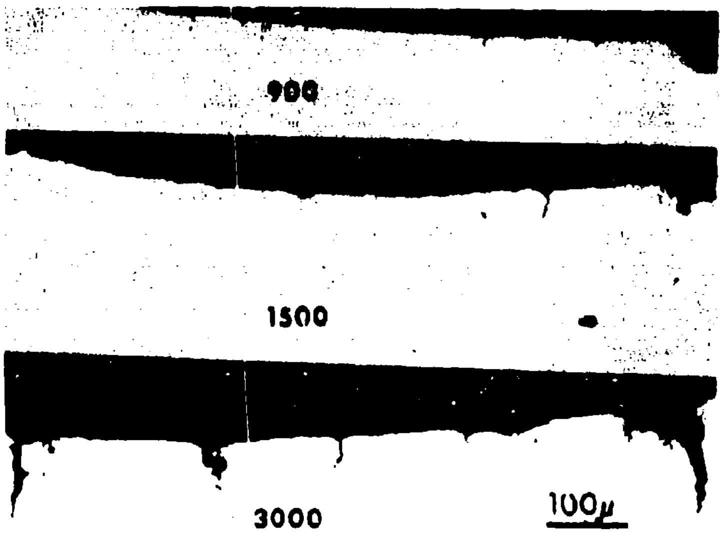

FIGURE 20 OPTICAL PHOTOMICROGRAPHS OF TRANSVERSE SECTIONS OF UNPLATED GUN BARRELS AFTER 900, 1500, AND 3000 ROUNDS (unetched)

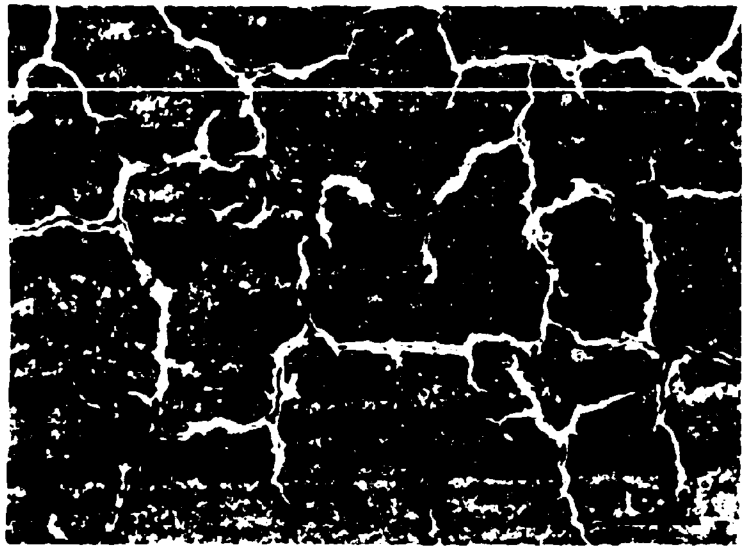

FIGURE 21 OPTICAL PHOTOMICROGRAPH SHOWING CRACK NETWORK BENEATH THE BORE OF UNPLATED STEEL AFTER 3000 ROUNDS (etched in nital)

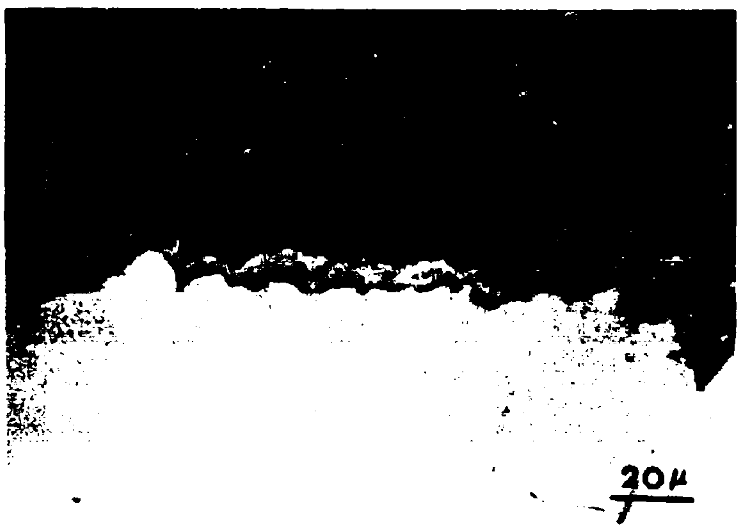

FIGURE 22 OPTICAL PHOTOMICROGRAPH OF ALTERED ZONE FORMED ON BORE SURFACE OF UNPLATED BARREL AFTER 900 ROUNDS

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13. ABSTRACT

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2. Gun barrels						
3. Chromium plating						
4. Chemical reactions						
5. Crack propagation						

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